TRANSMISSION MODE DETECTOR FOR DIGITAL RECEIVER

BACKGROUND OF THE INVENTION

Field of Invention

The invention relates to a transmission mode detector for digital receivers and,
more particularly, to a transmission mode detector compliant with the ETS 300 401
standard.

Related Art

According to the ETS 300 401 standard, a transmission frame is consisted of a null
symbol and several successive OFDM (Orthogonal Frequency Division Multiplex)
symbols. A receiving system has to detect the presence of the null symbol first in order
to verify the presence of broadcasting radio signals. The timing of the detected null
symbol is also used as a synchronization signal. Furthermore, there are four transmission
modes specified by ETS 300 401 for different broadcasting networks. For example,
the transmission mode I is usually used in terrestrial broadcasting in urban areas, while
signals broadcasted through satellites are typically in the transmission mode II or IV.
TABLE 1 lists the system parameters of the four transmission modes.

TABLE 1

Parameter	Mode I	Mode II	Mode III	Mode IV
L	76	76	153	76
K	1536	384	192	768
T_F	96ms	24ms	24ms	48ms
T_{NULL}	~1.297ms	~324μs	~168μs	~648μs
T_S	~1.246ms	~312μs	~156μs	~623μs
T_u	1ms	250μs	125μs	500μs
T_{gi}	~246μs	~62μs	~31μs	~123μs

The system parameters, such as the carrier number K in each OFDM symbol, the

symbol number L in each transmission frame, the symbol duration T_S, and so on, are different in different modes.   Since the receiving system cannot correctly decode the received data without the information of the transmission mode, the transmission mode must be first detected before the receiving system performs demodulation and decoding.

5   **SUMMARY OF THE INVENTION**

In view of the foregoing problem, the invention proposes a transmission mode detector that can quickly detect the transmission frames and has a simple structure.

To achieve the above object, the disclosed transmission mode detector includes: a RF tuner for receiving radio signal and generating IF (Intermediate Frequency) signals, 10 an envelope detector for filtering out the IF signals and generating a rough envelope waveform, a slicer for quantizing the rough envelope waveform into high and low potentials and generating binary signals, an A/D converter for sampling and digitizing IF signals to give digital signals, an I/Q (In-phase/Quadrature) De-multiplexer for extracting in-phase and quadrature signals in the OFDM symbols from the digital 15 signals, and a mode detection unit for determining the transmission mode of the transmission frame according to the envelope signal time period.   If the transmission mode is the mode II or III, then it further detects the transmission mode using the auto-correlation among the OFDM symbols.

The envelope detector of the invention contains: a diode, whose positive terminal 20 receives the IF signals, an RC network, whose one end connects to the negative terminal of the diode and the other end is grounded.   The disclosed slicer is a comparator, whose positive terminal connects to the negative terminal of the diode and whose negative terminal connects to a reference voltage and generates an envelope waveform.

BRIEF DESCRIPTION OF THE DRAWINGS

25   The present invention will become more fully understood from the detailed description given hereinbelow illustration only, and thus are not limitative of the present invention, and wherein:

FIG. 1 shows a system block diagram of the disclosed transmission mode detector.

FIG. 2 shows an embodiment circuit of the envelope detector and the slicer in the invention.

FIG. 3 shows a structure diagram of the glitch removal.

FIG. 4 shows a partial flowchart of the mode detection unit which uses the time period of the envelope signal for the mode detection.

FIG. 5 shows another partial flowchart of the mode detection unit which determines the mode II or III using auto-correlation.

FIG. 6 shows a waveform example of the IF signal y(t).

FIG. 7 shows an output envelope waveform y'(t) the envelope detector.

FIG. 8: shows the binary signal s(n) that pass through the slicer.

FIG. 9 shows the envelope signal s'(n) after glitch remover.

FIG. 10 shows a system block diagram of another embodiment of the disclosed transmission mode detector.

FIG. 11 illustrates the flow chart of the mode detector shown in the FIG. 10.

DETAILED DESCRIPTION OF THE INVENTION

With reference to FIG. 1, the transmission mode detector 10 contains a RF tuner 20, an envelope detector 30, a slicer 40, a glitch remover 50, an A/D converter 60, an I/Q De-multiplexer 70 and a mode detector 80. The signals processed by the RF tuner 20, the envelope detector 30 and the glitch remover 40 are analogue signals. The signals processed by the A/D converter 60, the I/Q De-multiplexer 70 and the glitch remover 50 are digital signals.

As shown in FIG. 1, the RF tuner 20 receives a RF signal from an antenna and generates an IF signal y(t). An example is shown in FIG. 6. The IF signal y(t) is turned into an envelope waveform y'(t) by the envelope detector 30. The envelope waveform y'(t) is converted into a binary signal s(n), i.e. H and L, by the slicer 40. After the glitch remover 50 removes the glitches in the binary signal s(n), it is turned into a data envelope signal s'(n). At the same time, the IF signal y(t) is converted into a digital signal y1(n) by the A/D converter 60. In-phase and quadrature signals of y2(n)

are extracted from the digital signal y1(n) by the I/Q De-multiplexer 70. Finally, the mode detection unit 80 determines the transmission mode according to the data envelope signal s'(n) and the I/Q signals.

As shown in FIG. 2, the envelope detector 30 contains a diode 31 and a RC network 32. The slicer 40 can be a comparator 41. The RC network 32 of the envelope detector 30 is equivalent to a low-pass filter. Since only signals with positive voltage values higher than the voltage drop of the diode, typically 0.6~0.7 volts, can pass through the diode 31, therefore the output terminal of the diode 31 gives the absolute valued waveform of the original signal. It should be noted that the null symbols to be detected have time periods of 96ms (transmission mode I), 48ms (transmission mode IV) and 24ms (transmission modes II and III). Thus, the appearance frequency of the null symbols is much lower than that of the IF signals (typically in the range of several MHz). In addition, the null symbols have a long duration ranging from several hundred μs to several ms. Therefore, a low-pass filter can be used to extract the envelope of the null symbols and the envelope with a rapid changing rate is smoothed and filtered out. The 3dB frequency f_0 of the low-pass filter used in the RC network 32 can be determined from the reciprocal of the time period of the null symbols. This RC value can be determined from the criterion ($R \cdot C = \dfrac{1}{2\pi f_0}$). The filtered output waveform y'(t) from the envelope detector 30 is shown in FIG. 7.

The smoothed envelope waveform signal y'(t) is now quantized into a hard-decision binary signal s(n), *i.e.*, high (H) or low (L), by the slicer 40. As shown in FIG. 2, the slicer 40 can be a comparator 41. According to the thumb of rules, the threshold δ can be chosen as the half of the peak-to-peak voltage of the IF signal or a little higher. As shown in FIG. 8, there are some unnecessary glitches in the binary signal s(n) after the slicer 40. Such glitches show up in places with low (S/N) signal-to-noise ratios and have a higher probability to cause false detections of frame timing. Therefore, the invention uses a glitch remover 50 to remove the glitches to improve the detection performance.

As shown in FIG 3, the core concept in the glitch remover 50 is that only the s(n) with low levels in successive L samples is considered as a valid null symbol. In addition, transitions followed by samples of less than successive L specific levels (high or low) are removed and then smoothed. That is, glitches are considered as signals that cannot have successive L samples staying at the same level. In this way, the glitch remover 50 can easily remove almost all the unwanted glitches. Therefore, the final output signal of frame timing s'(n), detected from the glitch remover 50, becomes very clear and is free from any glitch. The envelope signal s'(n) can be used as the frame timing base for the digital receiving system. The detected envelope signal s'(n) output from the glitch remover 50 is shown in FIG. 9.

According to the specification of ETS 300 401, there are three physical transmission frame durations. The frame duration is 96ms for transmission mode I, 48ms for the mode IV, and 24ms for both the modes II and III. Therefore, one can detect which transmission mode directly by calculating the period of the detected frame envelope signal s'(n).

The flowchart shown in FIG. 4 detects the transmission mode according to the envelope signal s'(n). The main technique in the procedure is to use a counter to compute the time period of each envelope signal s'(n). If the time period is found to be 24ms, then the transmission mode is the mode II or III, which is further determined according to the method shown in FIG. 5. A received signal with a detected 48ms-period transmission frame will be detected to be in the transmission mode IV. If the time period is 96ms, then it is in the transmission mode I. If the time period of the received signal is other than 96ms, 48ms or 24ms, the transmission frame is not considered as an effective signal. Furthermore, no null symbol being detected in a period of c*24ms indicates that there is no effective signal received.

Since the transmission modes II and III use the same transmission frame duration (24ms), the system needs to further distinguish the signal using some other method when a 24ms-period signal is detected. With reference to the algorithm shown in FIG. 5, the auto-correlation of the received signal is calculated based using the parameters of

the modes II and III. The one with a larger auto-correlation is selected as the detected transmission frame mode.

The received IF signal y(t) from the RF tuner 20 has the form of $I(t)\cos(2\pi f_c t) - Q(t)\sin(2\pi f_c t)$, where f_c is the central frequency of the incoming IF signal. After the IF signal y(t) is sampled and digitized by the A/D converter 60, the in-phase term $I(t)$ and the quadrature term $Q(t)$ are extracted separately for the following demodulator and the disclosed mode detection unit 80. It should be emphasized that neither the phase information for the sampling clock at the A/D converter, the carrier recovery for f_c, nor the precise symbol timing is required in the invention disclosed herein.

In FIG. 5, the auto-correlations in the modes II and III are computed starting from the rising edge of the frame envelope signal s'(n), which indicates roughly the starting time of the first OFDM symbol in a transmission frame. The correlation function in the mode II is

$$c_j = \left| \sum_{i=j}^{j+\Delta_2} y2(i+N_2) \cdot y2^*(i) \right|, \tag{1}$$

where $N_2 = 512$ and $\Delta_2 = 126$. The correlation function in the mode III is

$$d_j = \left| \sum_{i=j}^{j+\Delta_3} y2(i+N_3) \cdot y2^*(i) \right|, \tag{2}$$

where $N_3 = 256$ and $\Delta_3 = 63$. Let C_k and D_k be the maxima of the sequences $\{c_0, c_1, \ldots, c_{N_2+\Delta_2-1}\}$ and $\{d_0, d_1, \ldots, d_{N_3+\Delta_3-1}\}$, respectively. Then, C_k and D_k are the auto-correlations of y2(n) computed based upon the modes II and III parameters, respectively. In order to avoid the false detections when the S/N ratio is too low, the auto-correlations, C_k and D_k, for successive N symbols can be accumulated,

respectively; that is, $C = \sum_{k=0}^{N-1} C_k$ and $D = \sum_{k=0}^{N-1} D_k$. The transmission mode is then detected as the mode II if $C > D$ or the mode III if $C < D$. According to the statistics, a larger N value gives a smaller probability of making false detections.

FIG. 10 illustrates another embodiment of the transmission mode detector. The transmission mode can be directly detected by the mode detector 80'. The mode detector 80' accumulates auto-correlations for successive N OFDM symbols for each transmission mode. As shown in FIG. 11, the auto-correlations from mode I to IV are all computed respectively. The detected mode is the one with the largest accumulated auto-correlation. Note that, from ETS 300 401, $N_1 = 2048$, $\Delta_1 = 504$, $N_2 = 512$, $\Delta_2 = 126$, $N_3 = 256$, $\Delta_3 = 63$, $N_4 = 1024$ and $\Delta_4 = 252$.

In conclusion, the disclosed transmission mode detector first uses an envelope detector to filter out the IF signal generated by the RF tuner and generates a rough envelope waveform. Then the glitches in the rough envelope waveform are smoothed out by the glitch remover so as to obtain a glitch-free and correct envelope signal. The transmission mode is finally detected directly according to the transmission frame duration of the envelope signal. The mode II and the mode III are further distinguished by employing the auto-correlation method.

Certain variations would be apparent to those skilled in the art, which variations are considered within the spirit and scope of the claimed invention.